Change of quadriceps angle values with age and activity

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ABSTRACT

Objective: The lines connecting the anterior superior iliac spine to the center of the patella and the center of the patella to the tibial tuberosity make the quadriceps angle (Q angle), and this can be used as data for patellar alignment. We undertook this study to provide detailed information about the change of Q angle values with age and activity.

Methods: The study was conducted on 474 active (AG) (soccer players) and 765 sedentary (SG) boys (N=1239) from the age of 9-19, and the sedentary group also served as control to their age matched active counterparts. The statistical methods used were the student's t-test and the 3 way analysis of variance (ANOVA). The study was carried out in the laboratories of the Anatomy Departments and School of Physical Education and Sports, Istanbul and Hacettepe Universities between 2001 and 2003.

Results: The right and left Q angle values within both groups were statistically insignificant. The comparison of the groups showed a very high level of significant difference between the groups for both knees (AG right Q angle = 14.54 ± 4.76, SG right Q angle = 17.98 ± 3.24; AG left Q angle = 14.41 ± 4.61, SG left Q angle = 18.12 ± 3.55). The 3 way ANOVA showed that the age and physical activity had equally highly significant effects on Q angle values with a greater change in the active group's values.

Conclusion: We conclude that 1) children and adolescents have greater Q angle values than adults, 2) a change in quadriceps strength and tone, caused by both growth and activity, results in a decrease of the Q angle and 3) activity, particularly playing soccer in our study, has a remarkable effect on the Q angle.

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The quadriceps angle (Q angle) is the acute angle at the center of the patella formed by the intersection of the lines connecting the anterior superior iliac spine (ASIS) to the center of the patella (CP) and the center of the patella to the tibial tuberosity center (TTC). Both the force produced by contraction and the tone of a relaxed quadriceps muscle can affect the patellofemoral joint, and the force vector is related with the Q angle. In addition to the tone and the force produced during activity of the muscle, anatomical structures of the region also influence the Q angle. Hence, the Q angle has been related to knee problems such as patellofemoral pain syndrome, patellar dislocation and so forth.[1-4] Normal values of the Q angle have been reported and accepted by clinicians, but there is no consensus on the reference values,[5] and most of the study subjects were adults. The Q angles exceeding 15 degree in men and 20 degree in women are considered abnormal[6-8] for adults. The aims of this study were 1) to investigate the Q angle values of different age and activity groups and, 2) to determine if there is any change in Q angle values related to age and physical activity. The selected activity was soccer due to its high demand and it places on quadriceps activity. Since errors in the identification of anatomical landmarks have been reported to affect the accuracy of Q angle values,[5] in

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our study, all of the measurements have been made by 2 anatomists, deciding together where the landmarks need to be put.

Methods. The study group (N=1239) consisted of 2 main subgroups of active soccer players (AG) (N=474) and sedentary (SG) (N=765) Caucasian boys (9-19 years). These subgroups were further divided into 11 groups, according to their age and life style (AG 9-19 years and SG 9-19 years). All subjects were residents of the same city, coming from similar social levels. The active subgroup consisted of both, competitive and non-competitive pre-professional players of a professional soccer club, whereas the sedentary subjects were randomly chosen primary, high school boys and university students. The sedentary group also served as a control group to their age matched active counterparts. The active and sedentary groups were statistically comparable in their age (AG = 13.27 ± 2.84; SG = 13.47 ± 2.84), height (AG = 1.62 ± 0.16; SG = 1.60 ± 0.18), weight (AG = 52.72 ± 15.52; SG = 51.93 ± 15.61) and body mass index (AG = 19.67 ± 2.49; SG = 19.75 ± 3.39). The mean, standard deviation, minimum, maximum, and median values of both groups, and the homogeneity of the groups as proven by the student's t-test are shown in **Table 1.**

After a brief verbal explanation of the aim and the methods of the study, every subject should have a consent from their parents that they will be involved in the study. Before the measurements, all of the subjects were asked on a previous lower limb injury, and anybody mentioning any injury history was excluded from the study group. The Q angles of both knees (right and left) were measured and statistically evaluated. The measurements were performed on a horizontal examination table in the supine position, with both legs non-weight bearing straight and quadriceps muscles relaxed. Since interobserver variations of clinical measurements have been reported,[1] the reference points were determined by the agreement of 2 anatomists making all of the measurements. Any doubt on the landmark sites (ASIS/CP/TTC) that might create uncertainty or disagreement between the measuring anatomists led to the exclusion of the subject from the study group. Adhesive paper landmarks of 5 millimeter radius were attached on the anterior superior iliac spine, onto the center of the patella and the tibial tuberosity center. The Q angle value was measured as the acute angle between the line from ASIS to PC and from TTC to PC. Frequency tables and statistical comparisons were calculated with Statistical Package for Social Science (SPSS) 7.5 (SPSS Inc. Chicago, United State of America) for windows. All comparisons were made in each age group separately. The homogeneity within the groups according to age, height and weight were tested with the student's t-test. The effects of age (9-19), activity (AG/SG) and laterality (R/L) variables on the Q angle values were examined using the 3 way analysis of variance (ANOVA). A level of $p<0,05$ was accepted as significant.

Results. The equality of both subgroups in age, height and weight have been statistically evaluated and are shown in **Table 1**. The heights of active and sedentary groups were statistically different in the age groups,[14-16] where as the younger and older groups showed no significant difference (**Table 2**). The right and left Q angle values among each group were statistically indifferent, whereas the comparison of groups showed a very high level of significant difference for both knees (AG right Q angle = 14.54 ± 4.76, SG right Q angle = 17.98 ± 3.24; AG left Q angle = 14.41 ± 4.61, SG left angle = 18.12 ± 3.55). The mean, standard deviation,

Table 1 - Descriptive statistics of active and sedentary groups for age, anthropometric variables, and quadriceps angle (Q angle) with homogeneity of groups for age, height, and weight with students t-test.

Characteristics	Active group				Sedentary group				t-test for equality of means		
	Mean ± SD	N	Median	Range	Mean ± SD	N	Median	Range	t	degrees of freedom	Significant (2-tailed) *p* value
Age (years)	13.27 ± 2.84	474	13	9 - 19	13.47 ± 2.83	765	13	9 - 19	-1.235	1237	0.217
Height (meter)	1.62 ± 0.16	474	1.63	1.31 - 1.90	1.61 ± 0.15	765	1.63	1.14 -1.97	1.114	956.175	0.266
Weight (kg)	52.72 ± 15.5	474	50	27 - 87	51.94 ± 15.49	765	54	20 - 102	0.861	996.896	0.389
Right Q angle	14.54 ± 4.76	474	16	2 - 25	17.98 ± 3.23	765	18	9 - 27	-13.899	744.965	0.000
Left Q angle	14.41 ± 4.6	474	15	3 - 24	18.12 ± 3.54	765	18	10 - 28	-14.997	815.818	0.000

Table 2 - Descriptive statistics of Q-angle values and height for each age group of active and sedentary subjects.

Age (years)	Active group (N=474)							Sedentary group (N=765)						
		Right Q angle			Left Q angle				Right Q angle			Left Q angle		
	Height (meter)	Mean ± SD	Range	(Mean)	Mean ± SD	Range	(Mean)	Height (meter)	Mean ± SD	Range	(Mean)	Mean ± SD	Range	(Mean)
9	1.3882±0.04	20.29±2.64	16-25	(21)	20.35±1.77†	17-24	(20)	1.3818±0.0361	20.2±2.96	17-27	(20)	20.73±2.63	16-25	(21)
10	1.4366±0.0515	17.14±1.87†	14-22	(17)	16.97±2.72†	11-22	(17)	1.4398±0.0783	19.57±2.27	15-24	(19)	19.93±3.37	15-28	(19)
11	1.4676±0.0599	16.55±2.53†	12-22	(16)	16.5± .83†	11-21	(17)	1.4561±0.0759	19.63±2.5	13-25	(20)	19.83±3.91	10-25	(20)
12	1.5693±0.0899	16.47±3.49†	9-21	(18)	15.9±3.07†	9-22	(16)	1.5376±0.1218	19.63±2.98	15-27	(20)	19.87±2.89	15-25	(20)
13	1.6263±0.073	15.63±2.6†	10-19	(16)	15.81±3.1†	11-20	(16.5)	1.6039±0.0709	18.03±3.08	13-23	(18)	18.67±2.89	15-25	(19)
14	1.7327±0.0791†	14.41±3.07†	9-22	(14)	14.64±3.43†	7-19	(14.5)	1.6714±0.0831	17.93±3.49	13-25	(19)	17.80±3.22	12-24	(18)
15	1.7711±0.0477†	14.39±4.65*	7-21	(16)	13.83±3.79†	6-22	(14)	1.7196±0.0477	16.83±3.09	10-22	(16.5)	16.47±3.09	10-23	(16)
16	1.7612±0.0613†	11.15±4.51†	2-18	(10.5)	10.85±4.19†	3-20	(11)	1.73±0.0457	16.07±1.62	13-18	(15)	16.13±2.13	13-20	(15)
17	1.7773±0.0623	10.27±4.28†	2-19	(10)	10.36±3.14†	6-18	(10)	1.7611±0.0468	15.93±2.63	11-21	(16)	15.87±3.16	11-22	(15)
18	1.7907±0.0691	7.64±3.69†	2-16	(8)	8.14±3.39†	3-14	(8.5)	1.7778±0.0487	15.47±1.77	13-20	(15)	15.53±2.42	10-20	(15)
19	1.782±0.0514	6.4±4.28†	3-12	(4)	5.2±2.77†	3-9	(6)	1.7911±0.0649	14.8±3.32	9-20	(15)	14.67±2.53	11-20	(15)

* $p < 0.05$, † $p < 0.001$, Q angle - quadriceps angle

Table 3 - Main effects of age, activity, laterality and their combination on Q-angle values.

Dependent variable: Q angle	Tests between subjects efftect				
Source	Typed III sum of squares	degrees of freedom	Mean^2	F	Significant
Corrected model	23246.222*	43	540.610	58.320	0.000
Intercept	461401.613	1	461401.613	49774.856	0.000
Group	8007.882	1	8007.882	863.870	0.000
Age	14601.361	10	1460.136	157.516	0.000
Laterality	0.148	1	0.148	0.016	0.899
Group * age	1939.582	10	193.958	20.924	0.000
Group * laterality	9.908	1	9.908	1.069	0.301
Age * laterality	36.243	10	3.624	0.391	0.951
Group * age * laterality	22.088	10	2.209	0.238	0.992
Error	22562.627	2434	9.270		
Total	735643.000	2478			
Corrected total	45808.849	2477			

*$R^2 = 0.507$ (adjusted $R^2 = 0.499$), Q angle - quadriceps angle, F - analysis of variance test value

minimum, maximum and median values of the right and left Q angles of all active and sedentary age groups are shown in **Table 2**. In both the active and sedentary subjects, the highest mean values were measured in the 9 years old groups, and the lowest mean values were observed in the 19-year-old groups.

The 3 way ANOVA showed the equally significant effects of both, age and activity, on the Q angle values of the right and left knees. The combined effects of laterality and age, laterality and activity and laterality and age and activity were insignificant on the Q angle values. (**Table 3**)

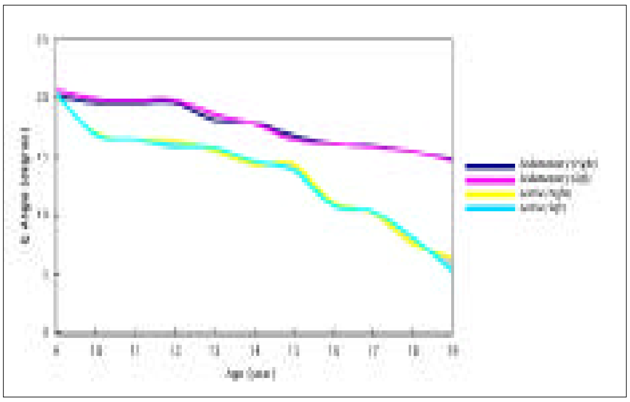

Figure 1 - Change of quadriceps angle values with age in right and left knees for active and sedentary groups.

Discussion. The Q angle has been related to knee problems such as patellofemoral pain syndrome, patellar dislocation and so forth and may contribute to the indication of a need for knee surgery.[1-4,10,11] Twenty-five to thirty percent of all knee injuries during running, occurring at the patellofemoral joint,[12] has led some authors to suggest that the alignment/orientation of the thigh, leg and foot may predispose individuals to patellofemoral pain.[4,13-15] Dislocation of the patella is a common disorder leading to considerable morbidity in young individuals.[1,16] Representing 0.4% of pediatric emergency admissions to surgical wards, annual incidence rates of 43/100,000 in children under 16 years and 107/100,000 in the age group 9-15 have been reported.[16] Smaller Q angles have been found in both habitual and traumatic dislocating knees in comparison with healthy knees.[1] The increase of Q angle values has been shown to shift the patella laterally and rotate it medially, increasing lateral patellofemoral contact pressures.[17] The decrease of values has been shown not to shift the patella medially, but to increase the medial tibiofemoral contact pressure by increasing the varus orientation.[17] A significant association between Q angle and quadriceps strength has been stated.[18] Smaller Q angle values of soccer players as compared with other sports athletes have been found, and related to quadriceps strength. Furthermore, in the same study, a negative association between the Q angle and years of playing soccer has been reported and this has also been related to quadriceps strength.[5] Even though the reliability of Q angle measurements and the relation of Q angle values to patellofemoral disorders are asserted to be debatable,[5,9] and despite the contention, that it is a less reliable clinical measure than previously was believed,[19-22] we believe that the Q angle, as a predictor of patellar alignment related to lower extremity biomechanics, still remains an important clinical indicator and a topic to investigate.

In our study, the Q angle values of both subgroups for both knees showed a negative association with age, as the decrease of Q angle values of active individuals was greater than the sedentary individuals. Without disregarding other biomechanical factors such as pelvic width, femur length and so forth, this finding was related to developmental differences, by our group of researchers, causing an increase in tone and strength of thigh musculature, and hence decreasing the angle. Since overall height, weight and body mass index as indicators of major anthropometrical specifications remained statistically indifferent between groups, the major factor causing the difference between active and sedentary groups in our study was related to the assumed quadriceps strength differences of both groups, caused by physical activity, particularly soccer. Because strength measurements of certain muscle groups are not involved in the study we can only conclude the effect of quadriceps muscle on the Q angle values among thigh musculature. As it is well known, the quadriceps muscle is dominant in soccer skills and patellar alignment, without disregarding other contributing muscle and soft tissue elements (such as Adductors). Another supporting finding to this interpretation was that the comparison of all age matched groups showed a significant difference of Q angle values except in the age 9 years group. This was the starting age to activity, and a statistically significant difference between matched groups started at 10 years and increased with age (**Table 2**; **Figure 1**). Since all members of active groups started with regular soccer training at 9 years of age and the training volume of the subjects increased with age, we can also assume that the activity factor is more effective than the age factor, influencing the Q angle values even in pre-pubescent periods of life.

This finding is in accordance with Hahn and Foldspang, who asserted mentioning that high strength and tonus of the quadriceps muscle tend to straighten the angle.[5] In their study, they reported that there is a significant difference between right and left Q angles, where our findings showed no difference between the sides and were therefore discordant with theirs. A quadriceps angle over 15 degrees is regarded as an anatomic risk factor in the etiology of patellofemoral pain syndrome.[3,6-8,23-29] In most of the studies, the subjects evaluated were adults and thus normal accepted values usually relied on the adults in those studies. In our study, 7 of 22 age groups had Q angle values less than 15 degrees, and only one of these 7 belonged to sedentary. Among Q angle values below 15 degrees, the youngest age was 14 in the active group and 19 in the sedentary. All groups younger than 19 in the sedentary, and 14 in the active groups had higher values. This means that 78% of the population had quadriceps angles in excess of normal accepted values. Remembering that all of the subjects were free of patellofemoral disorders, the general reference values for anatomic risk factors seem to be questionable for younger adolescents and children. According to our findings, physical activity of the individual seems to contribute and affect the Q angle so strongly, as to be recognized as one of its constituents. Since soccer requires high levels of quadriceps activity, it may affect the Q angle in a different manner than some other sports do.

In conclusion, the Q angle shows a negative association with age and physical activity. Although many other factors can be related with this finding, musculoskeletal maturation and the increasing strength of quadriceps muscle seem to be most relevant to our results, with a significant difference between active and sedentary individuals. In our study, the Q angle of male children and adolescents is found generally below 20 degrees but rarely below 15 degrees, especially if the individual is inactive. Despite that, all the subjects included in our study were free of patellofemoral disorders. Therefore, the reference values for the physiological range of the Q angle are questionable for younger adolescents and children, and further study is required. Having the same Q angle values as their sedentary counterparts in 9 years groups, and showing a greater change as the groups grow older, the active group draws out attention to the significant effects of physical activity, particularly soccer, on Q angle values.

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